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CHALLENGE: AN EXPERIMENTAL COMPUTER PROGRAM FOR RESEARCH ON ORGANIZING KNOWLEDGE TO IMPROVE RETENTION AND APPLICATION

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This research note reports on CHALLENGE, a theoretically based computer program undergoing experimental development. The purpose of this program is to assist students in organizing their knowledge of selected topical domains, and to provide a representation of how they have organized their knowledge during a given session. This research note summarizes the research background, and describes a cyclic series of pilot runs conducted to obtain critiques on screens, instructions, responses required of the user, and attitudes regarding the way the user had to interact with the program. The resulting revision, CHALLENGER II, is now being submitted to experimental testing in an instructional setting with college students.

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CHALLENGE: AN EXPERIMENTAL COMPUTER PROGRAM FOR RESEARCH ON ORGANIZING KNOWLEDGE TO IMPROVE RETENTION AND APPLICATION

EXECUTIVE SUMMARY

Requirement:

This effort is a portion of work initiated in response to guidance from the 1983 TRADOC Commander's Conference which emphasized the need to "improve officers' capability to think, plan and decide in developing an operations concept." At the request of the US Army Armor School, ARI conducted an analysis of the Armor Officer Basic Course (AOBC) to identify actions the School could initiate to accomplish this objective. A major conclusion of this analysis was that student officers were having difficulty in absorbing and organizing the large amount of information presented for application to tactical operations. ARI's recommendation, indorsed by the Armor School, led to the development of computer-tutors to train student officers to apply the types of cognitive strategies needed to organize tactical knowledge for application. These computer-tutors are interactive videodisk programs that are scheduled to undergo trail implementation at the Armor School during the first 9 months of 1988. The CHALLENGE program, described in this report, was developed as an experimental technique for evaluating the effectiveness of the interactive videodisk programs in improving organization of the student officers' tactical knowledge.

Procedure:

CHALLENGE is a theoretically based program developed for the purpose of capturing and depicting organization of a student's knowledge of a selected knowledge domain. This program has been subjected to a cyclic series of pilot runs and revisions. Purpose of these pilot runs was to obtain critiques on screens, instructions, responses required of user, and user's attitudes toward the way they had to interact with the program. CHALLENGE is now being submitted to experimental testing in an instructional setting with college students.

Findings:

The CHALLENGE program requests the subject to respond with keywords denoting major concepts and their supporting concepts they consider important to understanding the central topic provided by the program. While this initial task is perceived as similar to outlining, this perception changes to that of a networking task when the subject is asked to show how the major

concepts identified interrelate in his or her understanding of the central topic. Pilot runs resulted in extensive revisions of the program and, most importantly, expanded options for returning to add, delete, or change earlier responses.

Utilization of Findings:

CHALLENGE will provide a research tool for investigating how content and organization of knowledge upon entry into training affects learning, is altered by training, and how the resulting type of organization of the student's domain-specific knowledge affects retention and application to domain-relevant situations. If successful, computer-tutors of this type will provide training developers and instructors with programs needed to improve students' acquisition, retention, and application of knowledge to domain-relevant situations.

CHALLENGE: AN EXPERIMENTAL COMPUTER PROGRAM FOR RESEARCH ON ORGANIZING KNOWLEDGE TO IMPROVE RETENTION AND APPLICATION

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CHALLENGE: An Experimental Computer Program for Research on Organizing Knowledge to Improve Retention and Application

INTRODUCTION

In current training and educational settings instructors and reference texts are used to present a large amount of information to the students for initial learning. However, once the information has been presented, the actual learning depends on the extent and kinds of cognitive processing activities the student performs on the information. Typically, instructors are very limited in the time they can devote to tutoring students to make interrelationships among concepts that are needed to understand higher-level concepts or their application outside of the classroom. As a result, much of this new information either simply falls out of students' short term memory or, if memorized, is stored as discrete facts. When stored in this way, the knowledge lacks the interrelationships that will be needed for later retrieval and application.

Research to address this problem focuses on the experimental development and effectiveness of a computer-tutor that will cause the student to generate and defend interrelationships among facts, procedures and concepts needed to understand and apply a given topical domain. In contrast to conventional CAI, Adaptive CAI, and Intelligent CAI, the experimental cognitive-processing-tutor will not present the new lesson material for the given topical domain. Instead, these tutors will cause the student to perform the types of information processing required on information received in their regular instructional setting, and on their own prior knowledge, to develop well organized, goal directed, knowledge of the domain.

RESEARCH BACKGROUND

There is an extensive research literature on identifying organization of students' knowledge in specific instructional domains that has been developing since the early 1960's. Review of this literature reveals five general methods used to elicit subjects' knowledge of topical domains. These five are:

1. Interview and "think aloud" techniques (e.g., Collins, 1977; West, Fensham, & Garrardet, 1985). Research based on techniques of this type will be addressed in a subsequent phase of this research dealing with design of a tutor component.

2. Word association techniques (Johnson, 1964, 1965, 1967, 1969; Johnson, Curran, & Cox 1971; Shavelson, 1972, 1973, 1974; Shavelson & Stanton, 1975; Preece, 1976; Thro, 1978; Reitman & Rueter, 1980; McKeithen & Reitman, 1981; Champagne, Gunstone, & Klopfer, 1985; Gray, Mutter, Swartz, & Psotka, 1986; Naveh-Benjamin, McKeachie, Lin, & Tucker, 1986; and Mutter, Swartz, & Psotka, 1987).

3. Concept comparison techniques to rate or otherwise identify distance among stimulus concepts. (Johnson, 1967, 1969; Johnson, Cox, & Curran, 1970; Johnson et al., 1971; Shavelson, 1974; Wainer & Kaye, 1974; Shavelson & Stanton, 1975; Fenker, 1975; Preece, 1976; Diekhoff, 1983; Stanners, Brown, Price, & Holmes, 1983; Brown & Stanners, 1983; Champagne et al., 1985).

4. Concept mapping or networking with identified linkages (Holley, Dansereau, McDonald, Garland, & Collins, 1979; Champagne, Klopfer, Desena, & Squires, 1981; Fensham, Garrard, & West, 1981; Novak & Gowin, 1984; Novak, 1985; Champagne et al., 1985; Dansereau, et al., 1985).

5. Kelly repertory grids (e.g., Shaw & Thomas, 1978; Shaw & Gaines, 1982). This work is based on the *personal construct psychology* of George Kelly published in 1955. Shaw & Thomas (1978) describe two "...BASIC computer programs to elicit and analyse grids easily and clearly" (p.139). This technique is listed here because of its apparent relevance to our present research problem. However, the senior author only recently uncovered this literature and an attempt to review it in this paper would be premature.

Of the five types of methods listed above, discussion will focus only on research with word association, concept comparison, and concept mapping techniques. Since word association and concept comparison techniques share the same methodological problems to be discussed here, they will be treated as one group of techniques.

Word Association and Concept Comparison Techniques.

The majority of the research studies reviewed have utilized word association techniques or a variety of concept comparison techniques to elicit subjects' knowledge of the topical domain. To accomplish this, a set of concepts is selected to represent important nodes in the structure of the topical domain (approaches used to select concepts will be discussed below). Thus, all subjects receive the same set of concepts as stimulus words for use in word association or concept comparison techniques. The resulting representation of the organization of their knowledge is based on group data. In these studies, word associations or concept comparison data obtained from the "experts" are generally used to provide a reference or criterion for use in judging adequacy of the structure produced by the group.

We will focus on four problems that are common to the use of word association and concept comparison techniques in the studies reviewed. These are (1) limitations inherent in word association and concept comparison techniques, (2) the type of instructions usually given the subjects, (3) approaches used in selecting stimulus concepts from the topical domain, and (4) the usefulness of research findings based on group data.

Limitations inherent in word association and concept comparison techniques. The major limitation lies in the use of measures of interrelationships among stimulus concept words to infer the presence of a particular type of meaningful relationship. This has been of particular concern among researchers in science education (Stewart, 1979; Sutton, 1980). Johnson et al. (1971) described the word association test as a nonveridical assessment instrument similar in type to the MMPI with its value dependent on diagnostic normative data. Driver and Erickson (1983) assert that word association and concept comparison techniques elicit propositional knowledge without the links to specific events or phenomena needed for "knowledge-in-action" (p.43). Thro (1978, p. 972) rejected the "cognitive structure" label Shavelson (1972, p. 226) applied to the representation of students' knowledge obtained from these techniques and applied the more pragmatic label, "associative structures." Stewart (1979) argued that these techniques are useless in research on the teaching of science since they are unable to deal with propositional relationships between concepts. Amplfying on this point, Fensham et al. (1981) pointed out that "...In science learning the links between concepts are precise propositional statements that have very definite meaning" (p. 121). In short, the presence of the "correct" associative cluster does not necessarily mean the student has established the interrelationships which define the concept and, futhermore, the establishment of the desired concept does not guarantee its linkage to application. In contrast, research utilizing interview techniques (type 1, above) and concept mapping with explanation of relational links (type 4, above) has focused attention on students' frequent "misconceptions" of these interrelations.

Type of instructions given the subject. The problem of inferring a particular type of meaningful relationship is further complicated by the type of instructions given to the subjects. Shavelson (1974, 1975) pointed out that theoretical views on retrieval and decision processes have strong implications for interpreting students' responses obtained from word association and concept comparison techniques. Shavelson (1974) stated:

> The first is the importance of the context established by the instructions to the subject. They must be sufficiently detailed and clear to allow the subject to direct his search of LTM and to establish a criterion against which he can test alternative responses. (p. 237)

However, Shavelson, as well as other researchers in this area, were content with establishing context by instructing the subject, for example, to "think like a physicist" when the topic domain was Newtonian mechanics. Champagne et al. (1985) pointed out that cognitive structures derived from data collected using word association, or concept comparison techniques represent:

> ... a non-contextual structural organization of concepts. Although the structures obtained by these measures are in one sense contextual because the students are well aware that the content is science or physics, they are non-contextual in the sense that the concepts are not being applied to the solution of a specific task, for example, the comprehension of text or the solution of a numerical or qualitative problem. (pp. 165-166)

In other words, the subject is being asked to think about the relevance of the stimulus words to a given topic domain (e.g., physics), but is not given an objective or purpose the knowledge to be retrieved should serve. Thus, it seems likely that for any given topical domain, the specific associative structure elicited from the student will vary with variations in retrieval objectives given in the instructions. The ambiguous retrieval objective and the quick association procedures used in word association and concept comparison techniques appear to purposively minimize consciously directed thinking. It seems reasonable to assume that knowledge structures obtained by maximizing consciously directed thinking are more likely to reflect how students organize their knowledge for application than the structures obtained from the techniques reviewed above.

Approaches used in selecting stimulus concepts from the topical domain. It is interesting that there is very little discussion in this literature on strategies used in defining a topical domain for investigation and strategies for selecting concepts to use from that domain. In fact, instead of proceeding in a top-down fashion (identifying the structure of the topical domain and then selecting concepts), researchers have proceeded in an inverse direction, selecting concepts and then letting these concepts define the topical domain. The usual rationale given is limited to statements indicating that concepts were selected by instructors or experts in the scientific field either as being important in understanding that topical domain or as being a representative sample of concepts taught in that topical area.

"Important" may mean high in the hierarchy if the structure can be represented in this fashion. What would constitute a "representative sample" of concepts from a well organized topical domain? Apparently "experts" were never requested to describe the nature of the interrelationships among the concepts selected in this fashion. Instead, "experts" usually completed the same word association or concept comparison task administered to the students. The resulting organization of the concepts by the "experts" was then used as the criterion in evaluating students' organization of the concepts. Thus, while instructors or other experts may perceive patterns of interrelationships among the concepts, it is not clear what types of interrelationships they recognized, or that this structure was even being taught in the course.

Usefulness of research findings based on group data. Analytic methods based on group data are undoubtedly a more efficient way of reducing data than methods for dealing with each individual separately. Naveh-Benjamin et al. (1986), in the context of word association techniques, and Barsalou (in press), in the context of research on intra and inter-concept similarity, discuss the loss of information and the misinformation one obtains by using techniques involving averaging across subjects. Unless subjects' responses are highly homogenous, a representation of the organization of the group's knowledge seems devoid of meaning. Thus, within the context of the present research on development of a computer-tutor, it is important to focus on changes in associative structure within the individual rather than the group.

Concept Mapping or Networking with Identification of Linkages

A variety of techniques, which we will generically refer to as concept mapping, were developed by Rowell in 1974-1976 (as cited in Novak, 1985) and by Champagne et al. (1981) as assessment techniques. Champagne et al. (1985) have continued to use their technique, called Concept Structure Analysis Techniques (ConSAT), for evaluative purposes. The ConSAT is conducted in the context of individual interviews. The student is given a set of cards, each containing one concept word previously selected as important to the topical domain. The student is asked to arrange these cards on a large sheet of paper in a way that "shows how you think about the words". While or after completing the arrangement, the student is asked to explain why the words are arranged as they are. As the student identifies relationships between words, the interviewer connects the words with a line and labels the line with the relationship given by the student.

Shortly after Rowell's development of concept mapping, researchers at Cornell University begin using it not only in evaluation but as a direct instructional technique. Unlike Champagne's technique, concept mapping described by Novak and Gowin (1984) is performed as a part of regular classroom activities. Students are taught how to construct concept maps by arranging the initial key concepts from a given topic in a hierarchial fashion and then identifying the interrelationships linking these concepts. They are then instructed to expand the map by generating additional concepts and the relational linkages the student considers important to the given topic. The concepts and linkages generated by the students are discussed and critiqued in the course of teaching the topic. Novak (1985) and Novak and Gowin (1984) report applications of concept mapping in classes ranging from early school grade level into college classes. However, Novak reports that evidence for the effectiveness of this strategy is still largely anecdotal. Research applications are too limited in both duration and scope of the students' classes to produce important changes in students' knowledge structures and attitudes toward learning. Scoring criteria with nominal weightings are described in Novak and Gowin (1984). Novak (1985) reports that these scores measure something that is substantially different than what is assessed in the Scholastic Aptitude Test (SAT) or course exam grades. Novak attributes this to the failure of the SAT and course exams to assess meaningful learning.

Holley et al. (1979) and Dansereau et al. (1985) have conducted research on the effectiveness of a technique similar to concept mapping, but which they label "networking". Students were taught networking as a strategy for improving comprehension and retention of text. As in concept mapping, as described by Novak, students were taught to convert text into hierarchically organized node-link diagrams. An important difference however, is that in networking the student is taught to identify and use specific link types and types of text structure. Research findings have been mixed. In the Holley et al. (1979) study the networking group was superior to the control group on recall of main ideas from the experimental text. However, no difference was found in the Dansereau et al. (1985) study.

These techniques represent teaching strategies for inducing active learning of relational structures while, at the same time, providing a graphic reflection of the student's progress. While Dansereau and Novak might use different labels, they perceive their techniques as training students in metacognitive strategies that will improve their ability to learn as opposed to simply techniques for representing organization of knowledge. Novak advocates continuous use of concept mapping in instructional settings to develop students' conceptual meaning as opposed to rote learning of specific facts. However, Novak (1985) also reports resistance to introducing concept mapping into a curriculum dominated by rote learning. Many teachers saw it as a unwelcome diversion from teaching "basic facts." Development of a concept map was hard work and many students didn't like to do it. Nevertheless, students did develop concept maps and reported the experience helpful in identifying and understanding main points.

Concept mapping, as described by Novak and Gowin (1984) and Novak (1985), is the technique most directly relevant to the rationale underlying the development of the computer-tutor discussed in this paper. In addition to the use of concept mapping with students, Novak and Gowan recommend that instructors use concept mapping to identify the hierarchial structure and important relationships in the subject matter when planning instruction. This represents one method for defining a domain and identifying subdomains, along with their important concepts, a method that appeared to be missing in the word association and concept comparison research reviewed above.

RESEARCH OBJECTIVES

This research is designed to sequentially address two major objectives.

Phase 1. Objective: A computer-based program capable of capturing and depicting organization of a student's knowledge of selected topical domains.

Phase 2 Objective: A computer-tutor that embeds the program developed in Phase 1 with explicit tutor components that train students to apply appropriate cognitive strategies in the context of the given domain.

This computer-tutor will provide a research tool for investigating how content and organization of knowledge upon entry into training affects learning, is altered by training, and how the resulting type of organization of the student's domain-specific knowledge affects retention and application to domain-relevant situations. If successful, computer-tutors of this type will provide training developers and instructors with programs needed to improve students' acquisition, retention, and application of knowledge to domain-relevant situations.

PHASE 1: DEVELOPMENT OF THE CHALLENGE PROGRAM

Design Objectives

The objective in designing computer programs for use in this research was adopted from Wittrock's generative model of learning. To quote Wittrock (1986):

> According to my model of generative learning (Wittrock, 1981) comprehension is, essentially, the generation of a structural or conceptually ordered representation of the relations among the parts of the information to be learned, and between this information or these ideas and one's knowledge base and experience. (p. 308)

Wittrock distinguishes between "...generation of a structural or conceptually ordered representation of the relations among the parts..." (comprehension and knowledge acquisition) and generation of relations between information to be retained and arbitrary mnemonic "hooks" to achieve recall that will mirror the information presented.

Our goal in developing the CHALLENGE program is to provide a context for interaction with the computer that will induce students to examine interrelationships they can produce among information received in their regular instruction and also, to interrelate this information with their own prior knowledge and experience. In this sense, we want CHALLENGE to provide a context for activating in the students a metacognitive mode of thinking about how they are developing and organizing their knowledge about a given topic. In addition, the program must provide feedback in the form of a printout of the nodes and leaves students have produced, the cross-links between nodes, and data needed to construct a graphic representation of how they organized their knowledge during the session.

Programming of CHALLENGE programs

Programming has been accomplished by the second author using the Apple II Pascal 1.1 (based on UCSD Pascal 2.1) language. These programs run on an Apple IIe with two disk drives and a printer. The discussion which follows will describe the initial version (CHALLENGE I), summarize results obtained during pilot runs which led to the revised version (CHALLENGE II), and, finally, will describe CHALLENGE II and its associated analysis programs. CHALLENGE II is the version that will be used in research applications in a university setting during the 1987 - 1988 academic year.

CHALLENGE I

Overview of CHALLENGE I. CHALLENGE I, the initial version, is actually an umbrella title for a basic program that went through a series of revisions of screen designs, wording of instructions, and the mechanics of moving through the program. The initial screen informed the subject that the purpose of the program was to assist a person in thinking about information received in class and how it can be organized to achieve better understanding (of the central topic provided). The program then presented an overview of what the subject would be asked to do. It then proceeded to ask the subject to list the major concepts, procedures or things "you think you need to know to understand (the central topic)". The subject could enter up to 30 major concepts. However, if nine or more were entered the program would ask the subject to review the list and identify the terms "that will provide the best summary of what you need to know ..." and limit it to not more than eight terms. Following this, the subject was asked to rank order the major concepts in terms of their importance to understanding the central topic. Next, the subject was presented with the first major concept listed and asked to list concepts, procedures, or things "you think you need to know to understand (the major concept identified)." Again, the program was designed to accept up to 8 terms generated to support each major term. The subject was asked to rank order this second level of terms to show their relative importance to his or her understanding of the major concept for which they were generated. This procedure of generating second level terms for each major concept and then rank ordering the second level terms was repeated for all of the remaining major concepts. The final part of the program asked the subject to rate the importance of each second level term to each of the major concepts. A printout was then obtained showing what the subject had produced in each step of the program.

Pilot runs on CHALLENGE I. Five colleagues, all research psychologists, completed one session on this initial version of the program. The purpose of these pilot runs was to obtain critiques on screens, instructions, rankings and ratings required, and user's attitudes toward the way they had to interact with the program. Since the colleagues were volunteers in a work setting rather than students in an instructional setting, we had to select a topical domain that would represent a commonly shared knowledge base. The central topic, "Evaluating a basic research proposal" was selected based on the subjects' prior research training and subsequent job experience in this work setting. Note that "evaluating" is the goal the subject was given for retrieving his or her knowledge about a topical domain labeled "basic research proposals". Instructions used in the bulk of the earlier research literature reviewed above did not give the subject a specific goal for retrieving knowledge related to the stimulus words provided. For example, we would expect that the major concepts and supporting points generated would be different if the goal for this topical domain was "plan" a basic research proposal. We hope to use CHALLENGE to explore differences in organization of knowledge on retrieval to satisfy different goals such as "explain" topical domain X versus "apply" to solve a problem or make a decision.

Time to complete the program ranged from about 30 to 75 minutes. Each of the five subjects generated a different number of major concepts ranging from 3 to 7. These subjects generated an average number of supporting points ranging between 4 to 5 per major concept. The terms used for the major concepts and supporting points differed widely among the five subjects both in terms of levels of abstraction and thoroughness of coverage. The interrelationships of major concepts were obtained by rating the importance of each supporting point to each of the major concepts. These differences in terms used and the patterns of interrelatedness result in five, essentially idiosyncratic, organizations.

Subjects made clear one major problem they had in interacting with this version of CHALLENGE. The absence of options to go back and delete, change, or add both major concepts or second level terms imposed a serious handicap on the subjects. As a result, they were forced to retrieve, organize and record their thoughts in a serial, step-by-step fashion, without the option of going back and revising previous entries to make them mesh with the conceptual organization as they were developing it. Asking subjects in a work setting to generate major and supporting points important to their understanding of a topical domain is very analogous to asking for a "off-the-top-of-the-head" first draft.

In addition to the lack of editing options, subjects had not been given advance notice of what the central topic would be. Presession priming through individual or group discussions of the central topic would probably have been helpful. It appeared that subjects generally considered what they produced in this session as representing the beginning of thinking or brainstorming about the central topic as opposed to representing an organization of their knowledge of evaluating a basic research proposal. Thus, generation of higher and lower level concepts in this first session appears to represent more a preorganization retrieval of concepts without the opportunity to review and edit to arrive at a satisfactory "fit." As a result, CHALLENGE I was extensively revised to provide the printouts and editing options during the session in CHALLENGE II (described below).

However, even with these options, it is expected that an individual will require more than one session on the same topic before producing an organization that the individual will deem adequate. This expectation led to the design of the SUB-ANALYSIS confidence rating program as one approach to obtaining evidence of the subject's level of satisfaction with the concepts generated and their organization as depicted by the CHAL-ANALYSIS program.

Pilot runs also indicated the need for deleting the procedures for ranking major concepts and lower level concepts in order of their importance. Since this ranking task intervened between the generation of successive lists, it was perceived as slowing down and disrupting the continunity of the thinking process.

Several approaches to analyzing the data produced by the pilot runs were considered. A major concern, and one that has been addressed by Fensham et al. (1981), is providing data feedback that is easily interpreted by the instructor and the student. These considerations led to the development of the CHAL-ANALYSIS program that will be described below.

Finally, pilot subjects' critiques resulted in numerous revisions in the wording of program instructions, prompt symbols, and screen displays.

CHALLENGE II

Overview of CHALLENGE II. CHALLENGE II runs on an Apple IIe with two disk drives and a printer. Developed for research purposes, the program is initiated by the researcher for each student session. The researcher uses 2 disks, either the CHALLENGE program (if it is the student's initial session on the given topic) or the Re-CHALLENGE disk (if it is a repeat session on the topic), plus a student disk. When the CHALLENGE disk is booted up, the first screen will present a menu as follows:

1. Challenge program.
2. Chal-analysis program
3. Changer program, changes the mother node
4. Sub-analysis program
5. Formatter program
6. Exit to the Pascal system

Enter choice on the keyboard

If the student disk has not been formatted, the researcher will first choose #5 and the formatter program will accomplish the formatting. If the mother node (the central topic) has not been entered on the CHALLENGE disk, or if it is to be changed for this session, the choice of #3 will result in a request for the researcher to type in the Central Topic. The analysis programs, #2 and #4,.will be discussed later. Number 6 is included for convenience in identifying files on the student disk.

Running the CHALLENGE II program. Assuming the foregoing details have been taken care of, the researcher will choose #1 to initiate the first session. The initial screens from the CHALLENGE disk are to allow the researcher to log in the roster number assigned to this student, the session number for this student, and the date. The program is then ready for the student to take over.

Initial instructions on the CHALLENGE disk provide an overview of what the program will request the student to do. The student will be given the option of bypassing these instructions if he or she is familar with the program because of previous sessions on different topics. First, the student is asked to type in the major concepts perceived to be important to the student's understanding of the central topic given by the program. Prompts at the bottom of the screen allow the student to edit the list and to indicate completion. Next, the student is presented the major concepts entered, one by one in a succession of screens, and is asked to list supporting points he or she considers most important to understanding the relationship of each of the major concepts to the central topic. While creating each list, the student is given the option of changing or deleting terms.

When the student completes listing supporting points to the last major concept the program automatically provides a printout. This printout contains instructions for reviewing and editing the lists (Table 1) and the supporting points listed under each major concept (Table 2). The student is instructed to review the lists for terms that the computer has identified as duplications. If duplications are present, the student is requested to edit the lists so that words conveying the same meaning are used only once. In addition, the student may add, change or delete either major terms or supporting points before proceeding to the final stage of the program. The student also has the option of obtaining a printout after any change made.

Table 1

Printout of Instructions for Editing Keywords

INSTRUCTIONS FOR EDITING KEYWORDS

This printout identifies the central topic. It also lists in separate columns each major point and its supporting points that you provided.

Please review the keywords you have used and your organization of major points and supporting points to make sure this outline conveys your intended meaning.

Each keyword can be used only once. The printout will mark words that are very similar in spelling (*) or are identical (+). If some of your keywords are marked, review and decide where to change words or delete them so that words conveying the same meaning are used only once.

To enter an editing change, find the list number that is at the top of the list you wish to change. When you enter that number on the keyboard, the list you selected from the printout will appear on the screen. The screen will look like it did when you first created this list and you will use the keyboard commands, as you used before, to change, delete, or add terms to the list.

After you have entered the changes for a list you can choose to edit other lists or to obtain a new printout. You may edit and re-edit any list as often as you like. When you have finished editing on the computer, make a final printout of your work.

If you have any questions, please ask the experimenter for help.

Table 2

Printout of Lists Generated

Printout 1. 01 02 9 OCT 87

The central topic is Evaluating a basic research proposal.

List # 1. theorectical implic.	List # 2. type of study	List # 3. research lit.
replicate prev. findings	laboratory	sources of lit reviewed
extend existing theory	ethnographic	relev. of review to objectives
develop new constructs	field-controlled	lit. pro/con to objectives
scope of implications		
research objectives		

The central topic is Evaluating a basic research proposal.

List # 4. design	List # 5. resources req.	List # 6. relev. to army need
relev. depenent meas. to obj.	dollars	ARI work program
relev. indepent. meas to obj	subjects	army problems
quality of measures	time	political climate
tech. of quanitative analyses	operational disruption	
tech of qualitative analyses		
approp. of setting to obj.		
approp. of Ss to obj.		
data coll. procedure		

Note: # = term is very similar in spelling to other terms used. If identical in meaning, change or erase to avoid repetitions.
Note: + = term is repeated elsewhere in the list. Edit lists involved to change or delete repetitions.

Finally, the student is asked to show how the major concepts identified interrelate in his or her's understanding of the central topic by rating the importance of each supporting point to each major concept. Upon completion of these ratings, the student is provided with a printout (Table 3) containing instructions for reviewing and going back to change ratings made in any of the lists. The second part of this printout (Table 4) shows all of the supporting points generated in rank order by rating score under each major concept. When the student is satisfied with the rating of importance of each supporting point to each of the major concepts, a revised printout is produced and the SUB-ANALYSIS program is initiated.

Table 3

Printout of Instructions for Editing Ratings

INSTRUCTIONS FOR EDITING RATINGS

This printout identifies the central topic. In this printout all of your supporting points are listed in order of importance under each of the major points.

Next to each supporting point are two numbers. The first number indicates the strength of the relationship between the supporting point and the major point in the column heading; the number varies from 0 (not important) to 40 (most important). The second number indicates the list of supporting points in which that rating may be found.

Please study the ratings of importance to determine if they correspond to your understanding of the importance of each supporting point to the major point in the column heading. Circle any ratings that you would like to change and indicate whether the rating should be increased or decreased.

When you have finished reviewing the ratings, enter these changes on the computer. To change a rating, find the list number that is next to the rating you wish to change. When you enter that number on the keyboard, the list with the ratings that you previously entered will appear on the screen. Use the arrow keys, the Delete key and the number keys to delete the old ratings and to enter the new ones just as you did the first time.

After you have entered the changes for a list you can choose to edit other lists or to obtain a printout of the revised ratings. You may edit and re-edit any list as often as you like. When you have finished editing on the computer, you will be given a printout of your revised ratings.

If you have any questions, please ask the experimenter for help.

Table 4

Printout of Ratings Interrelating Major Concepts*

Printout I. Ratings: 0 (not important) ----> 40 (most important) 01 02 9 OCT 87

The central topic is Evaluating a basic research proposal.

theorectical implic.	type of study	research lit.
40 (1) replicate prev. findings	40 (2) laboratory	40 (3) sources of lit reviewed
40 (1) extend existing theory	40 (2) ethnographic	40 (3) lit. pro/con to objectives
40 (1) develop new constructs	40 (2) field-controlled	39 (1) replicate prev. findings
40 (1) scope of implications	40 (4) tech. of quanitative analyses	39 (1) extend existing theory
40 (1) research objectives	39 (4) tech of qualitative analyses	39 (1) develop new constructs
39 (3) sources of lit reviewed	38 (4) data coll. procedure	39 (1) scope of implications
39 (3) lit. pro/con to objectives	37 (3) sources of lit reviewed	39 (3) relev. of review to objectives
39 (4) relev. depenent meas. to obj.	37 (4) approp. of setting to obj.	38 (6) ARI work program
39 (4) relev. indepent. meas to obj	37 (6) army problems	35 (2) laboratory
39 (4) quality of measures	36 (5) dollars	34 (1) research objectives
39 (4) tech. of quanitative analyses	36 (5) time	34 (4) relev. depenent meas. to obj.
39 (4) approp. of Ss to obj.	35 (1) research objectives	34 (4) relev. indepent. meas to obj
39 (5) subjects	35 (5) operational disruption	34 (4) tech. of quanitative analyses
39 (6) ARI work program	33 (4) quality of measures	34 (4) tech of qualitative analyses
38 (3) relev. of review to objectives	1 (1) replicate prev. findings	33 (2) field-controlled
38 (4) tech of qualitative analyses	1 (1) extend existing theory	32 (2) ethnographic
38 (4) approp. of setting to obj.	1 (1) develop new constructs	1 (4) approp. of setting to obj.
38 (5) dollars	1 (1) scope of implications	1 (4) approp. of Ss to obj.
38 (6) army problems	1 (5) subjects	1 (4) data coll. procedure
38 (6) political climate	0 (3) relev. of review to objectives	1 (5) time
37 (2) laboratory	0 (3) lit. pro/con to objectives	1 (5) operational disruption
37 (2) ethnographic	0 (4) relev. depenent meas. to obj.	1 (6) political climate
37 (4) data coll. procedure	0 (4) relev. indepent. meas to obj	0 (4) quality of measures
34 (2) field-controlled	0 (4) approp. of Ss to obj.	0 (5) dollars
0 (5) time	0 (6) ARI work program	0 (5) subjects
0 (5) operational disruption	0 (6) political climate	0 (6) army problems

* Abbreviations and typos remain as entered by the subject.

Table 4 (Continued)

Printout of Ratings Interrelating Major Concepts

The central topic is Evaluating a basic research proposal.

design	resources req.	relev. to army need
40 (3) relev. of review to objectives	40 (5) dollars	40 (6) ARI work program
40 (4) relev. depenent meas. to obj.	40 (5) subjects	40 (6) army problems
40 (4) relev. indepent. meas to obj	40 (5) time	40 (6) political climate
40 (4) quality of measures	40 (5) operational disruption	39 (4) approp. of setting to obj.
40 (4) tech of qualitative analyses	39 (4) data coll. procedure	39 (5) dollars
40 (4) approp. of setting to obj.	39 (6) army problems	39 (5) time
40 (4) approp. of Ss to obj.	39 (6) political climate	39 (5) operational disruption
40 (4) data coll. procedure	38 (1) research objectives	38 (4) relev. depenent meas. to obj.
39 (1) research objectives	38 (2) field-controlled	38 (4) relev. indepent. meas to obj
39 (2) field-controlled	37 (6) ARI work program	38 (4) approp. of Ss to obj.
38 (1) replicate prev. findings	36 (4) tech. of quanitative analyses	38 (5) subjects
38 (1) extend existing theory	36 (4) tech of qualitative analyses	37 (1) scope of implications
38 (1) develop new constructs	28 (2) ethnographic	37 (1) research objectives
38 (1) scope of implications	14 (2) laboratory	37 (2) field-controlled
38 (3) lit. pro/con to objectives	4 (3) sources of lit reviewed	35 (3) lit. pro/con to objectives
38 (4) tech. of quanitative analyses	2 (4) approp. of Ss to obj.	34 (4) quality of measures
38 (5) time	1 (3) relev. of review to objectives	33 (1) replicate prev. findings
38 (5) operational disruption	1 (3) lit. pro/con to objectives	33 (1) extend existing theory
37 (5) dollars	1 (4) relev. depenent meas. to obj.	33 (1) develop new constructs
37 (5) subjects	1 (4) relev. indepent. meas to obj	20 (3) relev. of review to objectives
36 (2) laboratory	1 (4) quality of measures	5 (3) sources of lit reviewed
36 (2) ethnographic	0 (1) replicate prev. findings	0 (2) laboratory
36 (3) sources of lit reviewed	0 (1) extend existing theory	0 (2) ethnographic
2 (6) political climate	0 (1) develop new constructs	0 (4) tech. of quanitative analyses
1 (6) ARI work program	0 (1) scope of implications	0 (4) tech of qualitative analyses
1 (6) army problems	0 (4) approp. of setting to obj.	0 (4) data coll. procedure

The Re-CHALLENGE disk. Re-CHALLENGE differs from CHALLENGE only in that it loads, from the student disk, the lists of major concepts and supporting points generated in a previous session on the same central topic. The program starts by presenting the student with a printout presenting the previously generated lists. The program asks the student to consider whether or not his or her understanding of the central topic has changed since the previous session. The student is encouraged to review the major concepts and supporting points generated in the last session and to make whatever changes desired. The program proceeds from this point just as it did in the CHALLENGE program. Ratings of each supporting point to each major concept made in the previous session are not presented but must be done anew.

The SUB-ANALYSIS program. The objective of the SUB-ANALYSIS program is to obtain, (1) ratings of students' confidence in their understanding of the central topic and, (2) ratings of the extent to which the relative importance of major points and their interrelationships reflect students' understanding of the central topic. Since, generally, there are large individual differences in the way people distribute ratings along a rating scale, the SUB-ANALYSIS program is initiated by either the experimenter or the student setting a cutting point identifying the level of rating a term must have received to be considered an "important" relationship.

The student is first asked to rate, on a 0-100% scale, the level of confidence in his or her understanding of the central topic. Following this, SUB-ANALYSIS then presents the major concepts generated by the student, listed in order of importance, and a rating scale. Order of importance is based on the average rating of importance (final stage of CHALLENGE) of all supporting points to each of the major concepts. The student is asked to rate the extent to which this order of importance reflects his or her understanding of the central topic.

Finally, the student is presented a series of screens, each containing, in matrix form, a set of supporting points (rows) and all of the major concepts (columns). Cell entries are asteriks to indicate supporting points rated above the selected cutting score. Each screen contains a rating scale. The student is asked to rate the extent to which the pattern of asterikes reflect his or her understanding of each of the major concepts. To see the effects of different cutting scores, the student may be recycled through the SUB-ANALYSIS program and a printout (Table 5) will be automatically produced each time.

Table 5

Printout from SUB-ANALYSIS Program

```
The Central Topic is Evaluating a basic research proposal.
#5:01.02.TEXT[16]  is the File name.

9 OCT 87
01
01 02

Percent confidence in the Central Topic ----------------> 100
Agreement with the Rankings ---------------------------> 94

Ratings on the Major Points:
Cutting point set to -------------------------------->  32.9
Agreement with  theorectical implic. ----------------> 90
Agreement with  type of study -----------------------> 30
Agreement with  research lit. -----------------------> 100
Agreement with  design ------------------------------> 66
Agreement with  resources req. ----------------------> 32
Agreement with  relev. to army need -----------------> 68
```

The CHAL-ANALYSIS program. The interrelatedness ratings from the final step in the CHALLENGE (or Re-CHALLENGE) program are analyzed by the CHAL-ANALYSIS program to provide a representation of the organization of the student's knowledge during that generative session. This analysis, discussed below, shows the relative importance of each major concept to the central topic. In addition, it identifies the extent to which supporting points, originally generated under one major concept, are cross-linked or embedded in the understanding of other major concepts.

The CHAL-ANALYSIS program assumes that the relative importance of each major concept to the central topic can be reflected by computing the unweighted mean rating of all sets of supporting points on a given major concept. Thus, it is assumed that the greater the average rating, the higher is that major concept in the hierarchy of the topical domain as generated by that particular student. These means are shown in the CHAL-ANALYSIS printout (Table 6) in the bottom row of the first block of figures labeled "height statistics." The cutting point chosen, shown on the line below the mean ratings for each major concept, is not invoked in calculating the height statistics.

The second block of figures in Table 6 shows the number of supporting points which received an importance rating above the cutting point on each of the major concepts. It is assumed that major concepts are interrelated if at least one supporting point generated for concept A is given an importance rating above the cutting point on one or more of the other major concepts. It is also assumed that the greater the number of supporting points shared by two major concepts, the stronger their interrelationship.

It is assumed that interrelatedness can also be depicted as bi-directional, uni-directional, or no-relationship. Bi-directional means that one or more supporting points originally generated for concept A are subsequently rated as important for understanding concept B, and, vice versa, supporting points originally generated for concept B are subsequently rated as important for understanding concept A. Uni-directional means that one or more supporting points generated for major concept A are rated as also important to understanding concept B; however, supporting points generated for concept · are not rated as important for understanding concept A. No-relationship simply means that no supporting points generated for concept A are rated as important to understanding concept B, and, furthermore, none of the supporting points generated for concept B are rated as important to understanding concept A. These interrelationships can be derived from the last two blocks of figures in Table 6. However, they are explicitly tabulated in Table 7, the second page of printout from the CHAL-ANALYSIS program. Finally, the third page of printout from the CHAL-ANALYSIS program (Table 8) provides the complete matrix of supporting point ratings (rows) for each major point (columns).

Table 6

Page 1 of Printout from CHAL-ANALYSIS Program

File Name: #5:01.02.text
Name:
Date data was collected: 9 OCT 87
Roster Number: 01
Session Number:01 02
Central Topic: "Evaluating a basic research proposal".

Height statistics. (Mean Scores)

Major Nodes.							
1	2	3	4	5	6	Groups of leaves.	
40.00	7.80	38.00	38.20	7.60	34.60	1.	theorectical implic.
36.00	40.00	33.33	37.00	26.67	12.33	2.	type of study
38.67	12.33	39.67	38.00	2.00	20.00	3.	research lit.
38.50	23.38	17.37	39.75	14.50	23.38	4.	design
19.25	27.00	0.50	37.50	40.00	38.75	5.	resources req.
38.33	12.33	13.00	1.33	38.33	40.00	6.	relev. to army need
35.13	20.47	23.65	31.96	21.52	28.18		Unweighted column means.

Matrix of relatedness directions with the cutting point was set to 32.9.

Major Nodes.							
1	2	3	4	5	6	Groups of leaves.	
5.00	1.00	5.00	5.00	1.00	5.00	1.	theorectical implic.
3.00	3.00	2.00	3.00	1.00	1.00	2.	type of study
3.00	1.00	3.00	3.00	0.00	1.00	3.	research lit.
8.00	5.00	4.00	8.00	3.00	5.00	4.	design
2.00	3.00	0.00	4.00	4.00	4.00	5.	resources req.
3.00	1.00	1.00	0.00	3.00	3.00	6.	relev. to army need

Note: Positive number in column X and row Y indicates that Node X contains leaves of Node Y, ie X-->Y.

Bracket representation of relatedness directions.

Unwgt Col Means	Major Nodes	Relationships Among Nodes
35.13	theorectical implic.	1 - [-1(5)-2(3)-3(3)-4(8)-5(2)-6(3)]
20.47	type of study	2 - [-1(1)-2(3)-3(1)-4(5)-5(3)-6(1)]
23.65	research lit.	3 - [-1(5)-2(2)-3(3)-4(4) -6(1)]
31.96	design	4 - [-1(5)-2(3)-3(3)-4(8)-5(4)]
21.52	resources req.	5 - [-1(1)-2(1) -4(3)-5(4)-6(3)]
28.18	relev. to army need	6 - [-1(5)-2(1)-3(1)-4(5)-5(4)-6(3)]

Table 7

Page 2 of Printout from CHAL-ANALYSIS Program

File Name: #5:01.02.text
Name:
Date data was collected: 9 OCT 87
Roster Number: 01
Session Number:01 02
Central Topic: "Evaluating a basic research proposal".

The cutting point was set to 32.9.

Directionality listings.

Bi-directional	Uni-directional	No-relation
1 - 1	6 - 4	3 - 5
1 - 2		
1 - 3		
1 - 4		
1 - 5		
1 - 6		
2 - 2		
2 - 3		
2 - 4		
2 - 5		
2 - 6		
3 - 3		
3 - 4		
3 - 6		
4 - 4		
4 - 5		
5 - 5		
5 - 6		
6 - 6		

(blank)

Table 8

Page 3 of Printout from CHAL-ANALYSIS Program

File Name: #5:01.02.text
Name:
Date data was collected: 9 OCT 87
Roster Number: 01
Session Number:01 02
Central Topic: "Evaluating a basic research proposal".

Source Data for Computations

	1	2	3	4	5	6
1. theorectical implic.						
replicate prev. findings	40	1	39	38	0	33
extend existing theory	40	1	39	38	0	33
develop new constructs	40	1	39	38	0	33
scope of implications	40	1	39	38	0	37
research objectives	40	35	34	39	38	37
2. type of study						
laboratory	37	40	35	36	14	0
ethnographic	37	40	32	36	28	0
field-controlled	34	40	33	39	38	37
3. research lit.						
sources of lit reviewed	39	37	40	36	4	5
relev. of review to objectives	38	0	39	40	1	20
lit. pro/con to objectives	39	0	40	38	1	35
4. design						
relev. depenent meas. to obj.	39	0	34	40	1	38
relev. indepent. meas to obj	39	0	34	40	1	38
quality of measures	39	33	0	40	1	34
tech. of quanitative analyses	39	40	34	38	36	0
tech of qualitative analyses	38	39	34	40	36	0
approp. of setting to obj.	38	37	1	40	0	39
approp. of Ss to obj.	39	0	1	40	2	38
data coll. procedure	37	38	1	40	39	0
5. resources req.						
dollars	38	36	0	37	40	39
subjects	39	1	0	37	40	38
time	0	36	1	38	40	39
operational disruption	0	35	1	38	40	39
6. relev. to army need						
ARI work program	39	0	38	1	37	40
army problems	38	37	0	1	39	40
political climate	38	0	1	2	39	40

The height statistics (Table 6) and the directionality listings (Table 7) can be used to construct a graphical representation of how the student's knowledge of the topical domain was organized during this session. Currently, the graphics must be done by hand. Figure 1 presents an example of a graphical representation of how a subject organized his understanding of knowledge needed to evaluate a basic research proposal. In this example "important" is defined as supporting point ratings of 33 (40 maximium) or greater. The vertical dimension is based on the unweighted column means shown in the first block of figures in Table 6. Horizontal distance in Figure 1 is arbitrary and has no meaning. Connecting lines are bidirectional if no arrow head is attached; unidirectional if an arrow head is present.

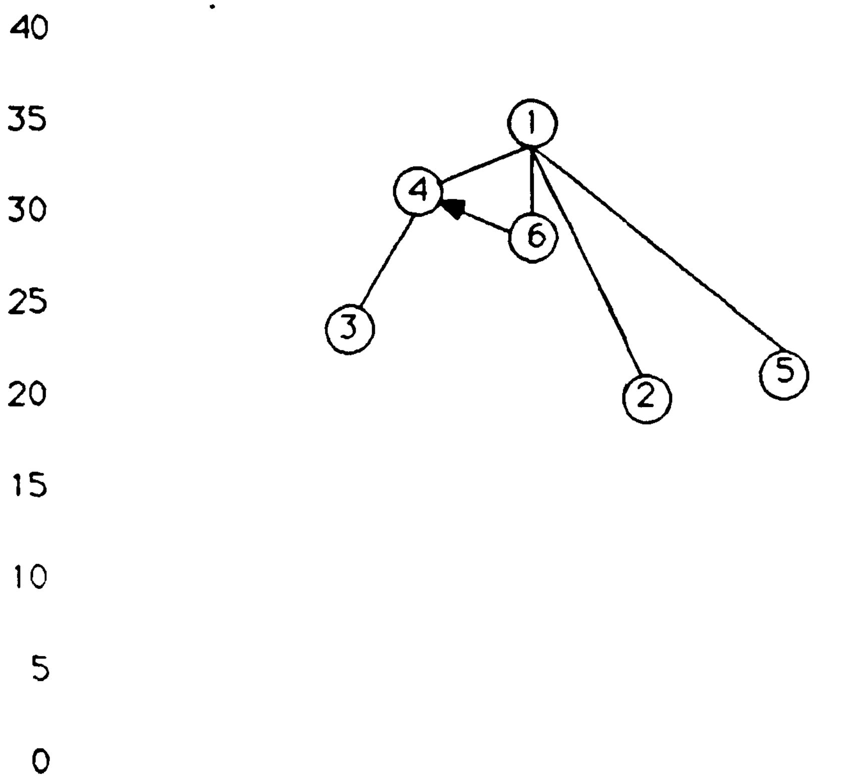
Note that not all possible bidirectional connections are drawn. The reason is simply to avoid a "can of worms" drawing. The rule is that as long as the subordinately rated (lesser unweighted means) major concepts have bidirectional relationships with the dominant (the largest unweighted mean) major concept, there is no need to draw lateral connections among these subordinate major concepts. However, all unidirectional connections must be drawn.

The bracketed representation of interrelationships is provided to aid in the interpretation of the graphic. The major concepts, identified by their number in the brackets, are ordered from left (most qualifying supporting points) to right (fewest qualifying supporting points). When two or more embedded major concepts possess the same number of qualifying supporting points they are shown in parentheses with an equal sign. In Figure 1, note in the bracketed representations of relationships among nodes (Figure 1), that major concepts #1, #2 and #6 embed one or more supporting points (rating score of 33 or greater) from each of the other major concepts. The relationship between #6 and #4 is unidirectional. The supporting points originally generated as important to understanding #6, "Relevance to Army need" were not rated important (rating scores less than 33) to understanding #4, "Design". However, some of the supporting points originally generated as important to understanding "Design" were rated as important to understanding "Relevance to Army need". Also note that the bracketed representation make clear that there is no direct interrelationship between major concept #3, "Research Literature", and #5, "Resources Required". This is not made clear in the graphical representation due to the effort to avoid the "can of worms".

The major shortcoming of Figure 1 is that it does not show the supporting points which establish the interrelationships among the major concepts. Currently, the complete matrix of rating scores shown earlier in Table 8 is the only concise way to present this information.

Pilot #50101-80

Evaluate a Basic Research Proposal

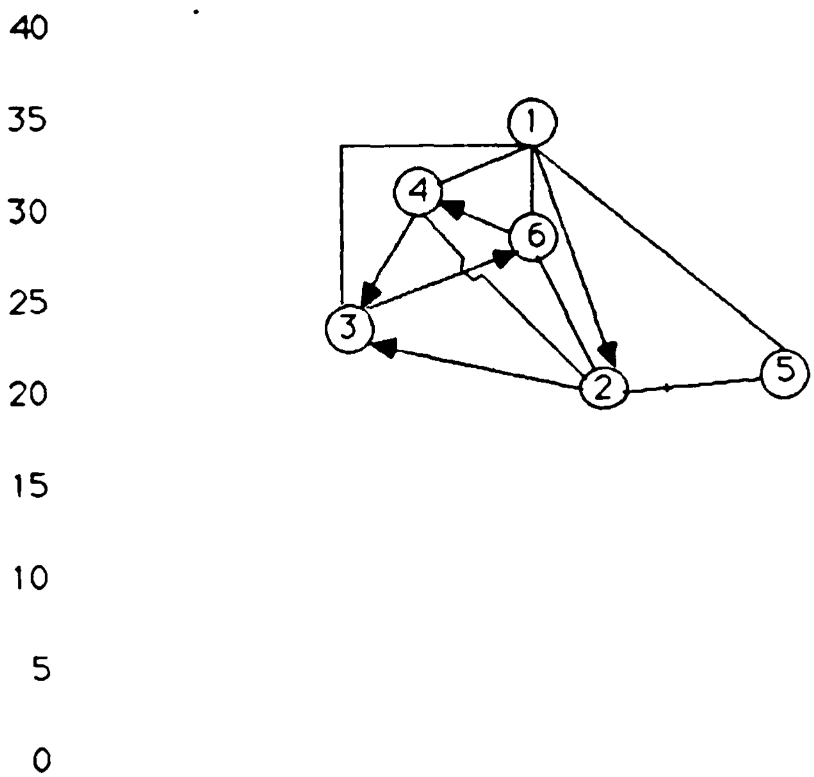


Mean Ratings	Major Nodes	Relationships Among Nodes
35	1. Theoretical implications	1-[4-(2=3=6)-5]
32	4. Design	4-[1-5-(2=3)]
28	6. Relevance to Army need	6-[(1=4)-5-(2=3)]
24	3. Research literature	3-[1-4-2-6]
22	5. Resources required	5-[(4=6)-(1=2)]
20	2. Type of study	2-[4-5-(1=3=6)]

Figure 1. Interrelationships based on supporting point ratings equal to or greater than 33 (out of possible 40).

Pilot #50101-90

Evaluate a Basic Research Proposal



Mean Ratings	Major Nodes	Relationships Among Nodes
35	1. Theoretical implications	1-[4-(6=3)-(5=2)]
32	4. Design	4-[1-5-(2=3)]
28	6. Relevance to Army need	6-[(4=5)-1-2]
24	3. Research literature	3-[1-6]
22	5. Resources required	5-[(4=6)-(1=2)]
20	2. Type of study	2-[4-5-(3=6)]

Figure 2. Interrelationships based on supporting point ratings equal to or greater than 36 (out of possible 40).

Figure 2 illustrates the use of the CHAL-ANALYSIS program to explore the way the subject uses the rating scale to define "importance". In this figure the cutting score for supporting point ratings was raised to 36, or 90% of rating points possible. It can be noted from Table 8 that this person tended to use the extreme ends of the rating scale with virtually no ratings in the middle of the scale. As a result, lowering the cutting score from 33, shown in Figure 1, to 20 did not require any change to Figure 1. Raising the cutting score, as shown in Figure 2, resulted in an increase in unidirectional relationships. Since this produced an unidirectional relationship between major node 1 and 2, it was necessary to draw in the bidirectional relationships connecting node 2 with nodes 4, 6, and 5. Whether or not height ratings and the directional relationships shown have significance for the retrieval search this individual would employ in a similar context remains to be seen.

SUMMARY

CHALLENGE II is a program undergoing experimental development. It will be tested in research designed to evaluate its usefulness in assisting students to organize their knowledge of topical domains. By the same token, this research will test its effectiveness in representing how the students have organized their knowledge during a given session.

The CHALLENGE II program does not yet include a tutor component. However, the generative thinking this program requires of the student is expected to provide a context for activating a metacognitive mode of thinking about how he or she is developing and organizing knowledge of a topical domain. This technique is expected to produce an organization of knowledge that is different than the associative structures obtained from word association and concept comparison techniques. Presenting students with a central topic and an objective to satisfy in generating the retrieval and organization of their knowledge is expected to maximize consciously directed thinking. In doing this, the student is identifying where linkages exist. Currently, labeling the type of relational link thought to exist between concepts must be accomplished by querying the student following completion of the session on the computer. It is anticipated that labeling of relational links will become an important feature of the phase 2 computer-tutor program.

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